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SUPPORTING EFFECTS-BASED OPERATIONS (EBO) WITH INFORMATION TECHNOLOGY TOOLS: EXAMINING UNDERLYING ASSUMPTIONS OF EBO TOOL DEVELOPMENT PRACTICES

Rensselaer Polytechnic Institute

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This effort examined, from both theoretical and empirical perspectives, major paradigms underlying the support of strategic decision processes in hyper-competitive environments. The primary research objectives were to (1) to develop a theoretic schema of approaches to strategic decision support, and (2) to provide an empirical research plan and detailed experimental design to assess the efficacy of the different paradigms.
This final report identifies four major paradigms or "schools of thought" of strategic decision support: autonomous, directive, predictive, and emergent. The proposed paradigms are offered to illustrate how recent EBO tool development approaches may be classified and subsequently characterized based upon their inherent gravitation to a particular decision support paradigm.

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Abstract

Throughout the course of history, great leaps in progress and understanding have been facilitated through the questioning of basic assumptions. In an effort to uncover critical opportunities and vulnerabilities within effect-based operations (EBO), similar questions must be posed to our current assumptions underlying EBO tool development practices. Required for these assumptions to be examined is a shared understanding of strategy formulation as an intensely human process. The breadth of approaches used in recent years to help commanders formulate effects-based courses of action (CoA) is quite diverse including expert systems, Bayesian networks, and scenario analysis. All of these approaches represent best guess assumptions of how to codify aspects of the strategy development process, often with out regard for the principles of automation. The adverse unintended consequences made possible from this neglect are wide ranging, including the potential to inadvertently foster convergent vs. divergent thinking, conditioning commanders and policy makers to accept a dangerously limited view as an accurate model of “real world” threats. Imperative to avoiding this conceivable eventuality is a strategic perspective on EBO tool development practices. Identified in this paper are four major paradigms or “schools of thought” of strategic decision support: autonomous, directive, predictive, and emergent. The proposed paradigms are offered to illustrate how recent EBO tool development approaches may be classified and subsequently characterized based upon their inherent gravitation to a particular decision support paradigm.

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Research Imperative

The Air Force Scientific Advisory Board (SAB) conducted a science and technology review of the Information Directorate's Rome Research Site in November of 2003. The purpose of this bi-annual panel review is to assess the quality and long term relevance of research & development efforts being conducted by the USAF. AFRL/IF is in charge of supporting a majority of USAF command and control efforts including EBO. When reviewing this area the SAB panel developed a strong belief that:

> "IF's EBO program is overly focused on tools, like CAT, without an accompanying vision and appreciation for the underlying decision science upon which modern C2 must rest… C2 is **critically important** to the warfighter, is a huge force multiplier, and requires our **very best scientific effort**… Although there is a lot of good work going on in C2, there is concern about a culture which appears to favor tool development without a clear overall plan of research in C2."

The proceeding research is an effort to address this observed deficiency in basic decision science research through general study of the dominant paradigms of EBO tool development. Following the presentation of a broad classification scheme for EBO tool development practices, the AFRL/IF EBO tool development practice underway as of August 31, 2004 are classified in tabular format.

Introduction

In recent years, a wide variety of approaches have been used to develop tools that help decision makers generate courses of action (CoA), for example Bayesian networks, expert systems, and scenario generation. The diversity and fundamental differences of these approaches has prompted the need for a basic understanding of the underlying assumptions upon which the approaches are based. Although the approaches differ in many aspects, each approach may be viewed as pertaining to a major "school of thought" or decision support paradigm. Tool development approaches thus may be classified and subsequently characterized based upon their inherent gravitation towards a particular decision support paradigm. Questioning the basic assumptions of tool development practices is crucial to avoiding potential adverse unintended consequences that may occur as a result of the specific limitations inherent to a particular approach or family of approaches. Decision support paradigms operate at the family level, showing how approaches may be aggregated based upon underlying commonalities. This low resolution method of analysis is not meant to be comprehensive. It serves only to reinforce the focal premise of this paper, the need to question the basic assumptions underlying tool development practices in an effort to avoid potentially serious adverse unintended consequences.

Never before in history has the velocity of information been so fast, the speed of decision making so quick, and the potential for adverse unintended consequences so great [1]. We live in a world where the competitive landscape continues to shift toward hyper-competition, where strategic decision makers are forced to continuously contend with numerous multi-criteria decisions that must be made with:

- incomplete data
- uncertain information
- ambiguous goals
- high stakes
- time pressure
- lethality of weapons
- and against intelligent adversaries [2-4]

The characteristics of the hyper-competitive environment of today represent a strong divergence from familiar past competitive experiences. The cold-war era was black-and-white, where the United States had a clear picture of who were allies, adversaries, and neutrals [5]. Over the years, intelligence analysts had developed high fidelity models of enemy doctrine, capabilities, and even socio-cultural axioms. The relative certainty of these adversarial models removed a great deal of ambiguity from the planning process. Today much of that certainty is gone as our nation faces new challenges in the form of transnational terrorist threats [6]. Once what was quantifiable or predictable becomes irrelevant. Adversaries no longer adhere to set, understood, or even rational (that is "western") rules of engagement. In addition, they are constantly evolving their tactics (i.e. asymmetric warfare), adapting in response to employed defensive measures, and construing all together new methods of conducting warfare. To combat an intelligent, "non-rational" adversary requires a new way of conducting operations with increased precision and efficiency. In short, there is a need for a basic realignment in war planning as the character of warfare is changing and the degree of that change is considerable [7, 8].

Effects Based Operations

Very recently an emphasis has been placed on developing tools to support the concept of "effects-based" planning and operations, where an "effect" refers to the full range of physical, functional, or psychological outcomes, events, or consequences resulting from specific applied military/non-military force [9, 10]. Effects come in an array of forms including direct, indirect, cascading, cumulative, collateral, and systemic (for definitions see Air Combat Command EBO White Paper [10]). Recent surveys of the literature have observed that effects-based operations has no agreed upon definition, but rather there exists many variations and descriptions of the evolving concept [11, 12]. For the purpose of this paper, Effects-based operations (EBO) will be defined as actions taken against enemy systems designed to achieve specific effects that contribute directly to desired outcomes [10]. Further, in a methodological form EBO may be defined as a methodology for planning, executing, and assessing operations to attain desired strategic

effects that contribute directly to military and political objectives by shaping the behavior of friends, foes, and neutrals in peace, crisis, and war [5, 7, 10, 12, 13].

An emphasis on effects as they relate to achieving objectives adds an element of rigor to strategy formulation and execution, requiring decision makers to articulate why a set of actions will produce a resulting set of intended and unintended effects through "causal linkages". Table 1 presents a graphical depiction of causal linkages to aid in comprehension of the concept.

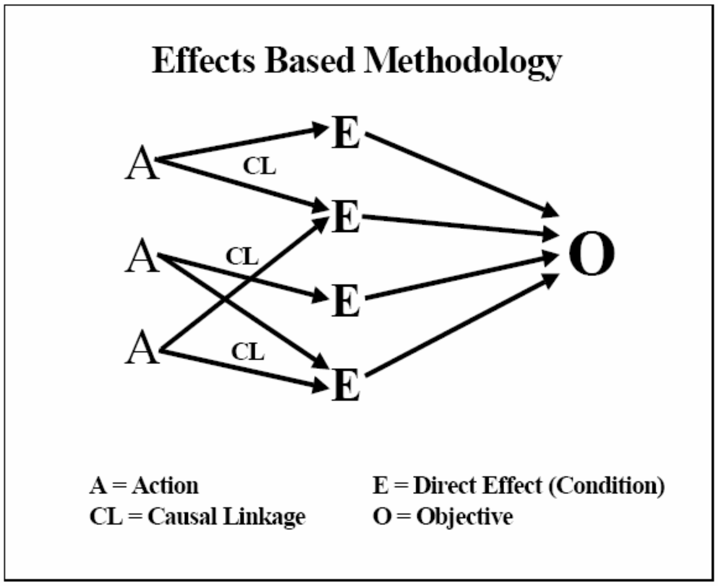

Table 1: Graphical Depiction of EBO Methodology [10]

Achieving objectives requires influencing enemy systems, which may be accomplished by affecting either physical or behavioral/psychological targets. To conduct operations in the behavioral/psychological realm requires an understanding of opponent adversaries, viewing them as a complex adaptive system that includes soft factors such as ideologies, perceptions, and will. The complexity of these soft factors solidifies EBO CoA generation as a human intensive process. Decision makers must rely heavily upon their training/expertise and support tools to operate in the realm of behavioral/psychological effects, where focus is placed upon gaining control of an enemy rather than destroying it through a war of attrition. The principle that the most advanced form of warfare is to subdue ones enemy with out fighting is attributed to Chinese theorist Sun Tzu:

> "Those skilled in war subdue the enemy's army without battle. They capture his cities without assaulting them and over-throw his state without protracted operations" -Sun Tzu [14].

In an era of precision weapons, it makes intuitive sense that precision operations should follow. The recent emphasis on effects-based operations by senior defense officials is due to its promised ability to provide this decisive capability and the advantage it affords strategic decision makers.

Decision Support Paradigms

In designing technology to support human decision makers (commanders) generate and select effects-based CoAs, a wide variety of approaches have been employed each with its own merits and limitations. All of these approaches were based upon assumptions made by tool designers and developers as to how the tool could best impact CoA generation. A cause for concern lies in the observation that developers frequently employ approaches based upon their merits with traditionally little concern for how the approach may compare to similar approaches to solving the same problem [15]. This lack of reasoning among approaches indicates an inadequate application of decision support systems engineering principles [16], yielding the potential for adverse unintended consequences as an approach that is not well suited for a particular environment or task may be chosen by a developer. Supporting the concept of a lack of reasoning between approaches is the complementary observation that a good deal of the historical information on decision support system (DSS) design is technically focused and non-comparative in nature, typically viewing a single approach in isolation [17]. ***It is imperative that the efficacy of the basic assumptions underlying the approaches are challenged and compared prior to technology being codified and fielded in support of strategic planning***.

At the strategic level the possible adverse unintended consequences are wide ranging however one is of particular importance and deserves further discussion. That is the potential to inadvertently foster convergent vs. divergent thinking, conditioning commanders and policy makers to accept a dangerously limited view as an accurate model of “real world” threats, affording a “false” situational awareness. Effects-based CoA generation tools may inadvertently lead strategic decision makers down a narrow path, creating “blind spots” in the organizations perception of environmental threats [18]. Imperative to avoiding this conceivable eventuality is a strategic perspective on EBO tool development practices. This implies a great responsibility for the development community to understand how humans formulate courses of action and consider alternatives in the face of adverse uncertainty. Tool developers must use this knowledge as a critical lens to further question their underlying assumptions and justification for selecting a particular approach from among competing alternatives.

Specifically identified in this paper are four major paradigms or “schools of thought” of strategic decision support: autonomous, directive, predictive, and emergent. The proposed paradigms are offered to illustrate how recent EBO tool development approaches may be classified and subsequently characterized based upon their inherent gravitation to a particular decision support paradigm. This classification is not meant to be comprehensively exhaustive. They are presented to facilitate discussion on the need for EBO tool development to properly address improving decision making capabilities in the “real world”. This paper denotes the distinctions between the various decision support paradigms through a conceptual discussion of their defining aspects and implications on technology design.

Autonomous Paradigm

One of the easily understood paradigms of decision support is the autonomous paradigm which is characterized by machine autonomy from the human decision maker. The autonomous paradigm can be represented by fully automated decision support systems: for example, real time software that matches mission objectives and available resources to prioritize targets.

The central idea of the autonomous paradigm is the belief that a certain task or set of tasks can be fully automated, thus removing the human from the decision process. This is generally accomplished by developing a set of rules that would be applied to the data being processed by the decision support system. The developed rules are assumed to be part of a closed loop system, meaning that there are typically very few exceptions to the rules, allowing for the system to run for the most part autonomous of human control.

A foundational insight made by Simon in the field of decision science is that decision problems may be seen to exist on a continuum from programmed routine, repetitive, well-structured, easily solved to the polar opposite end of the spectrum being non-programmed, new, novel, ill-structured, difficult to solve [19]. If viewed in this manner, tasks that fall under the autonomous paradigm would generally be located at the lower end of the decision continuum, representing the very well structured, routine, repetitive tasks that are easily formulated and optimized. Typically autonomous systems operate in relatively stable environments as exceptions to the predefined rules would require human intervention.

The advantages of developing a DSS under the autonomous paradigm are straightforward. It moves the task from human to machine, eliminating human error and allowing the decision maker to focus on more pertinent, strategic, higher level decision issues. Certainly any task that is amenable to being fully automated in this fashion should be due to the obvious advantages, but is it possible that technologists have in the past and even today are continuing to develop autonomous tools for tasks or environments for which they are ill-suited? The limitations of autonomous systems are equally as clear as their advantages; exceptions to predefined rules can cause disastrous results, with the severity of the mistake being dependent upon what information is overlooked, discarded, misinterpreted, or otherwise mishandled.

So why then if the limitations of such systems are so clear would a DSS developer attempt to fit a decision task under the autonomous paradigm if it really would be better off being developed under a different paradigm? The answer can be partially found by studying the law of the hammer, which states that if you give a child a hammer he or she will use it on everything encountered [15]. Hopple goes on to explain that:

> "often individuals who devote their professional careers to learning and applying decision analysis, artificial intelligence, or some other domain will be understandably reluctant to admit that tools and methods outside

> their domain may be equally or even more appropriate to solve a given problem" [15].

It is possible that the limitations of the paradigm are overlooked or trivialized due to narrow, specialized background and nature of the technological developers. A limited focus mentality is typical for a human specialist, however it represents a significant danger to developing effective strategic decision support tools in an era when rarely any single individual or community of expertise will be capable of dealing with the complexity of current military operations [20].

When developing tools under the autonomous paradigm it is important for developers to understand that full automation does not simply supplant human activity but rather changes it, often in ways unintended and unanticipated by the designers of the automation [21]. To gain a better understanding of the assertion of possible unintended consequences prior to operational fielding requires technologists to conduct testing (evaluation assessments) on the tools in simulated environmental contexts similar to the conditions that the tools will face once fielded [1, 22].

Directive Paradigm

The directive paradigm of decision support is characterized by machine centered guidance of either human decision makers or other technological components. This paradigm may be represented by limited interaction, machine centered decision support systems: for example, case based reasoning techniques and other forms of prototypical expert systems.

The central focus of the directive paradigm is the formulation of procedural knowledge (step by step instructions) based upon available descriptive knowledge (data or information) that has been collected regarding the current decision making situation. The prescriptive direction may be used to orchestrate both human and machine behavior, potentially circumventing the human decision maker entirely by directing other technological components to accomplish the task at hand. Human interaction with a directive DSS thus may range from moderate to non-existent. The human decision maker might be called upon to input certain values, make simple choices, and conduct limited analysis but as in the autonomous paradigm, the principle decision maker will remain the pre-programmed machine (i.e. software…, which essentially is the developer acting as the situational commander).

The advantages of DSS tools under the directive paradigm have traditionally been linked to knowledge engineering. Directive tools aim to formalize procedural knowledge. The advantages of such codified knowledge are clear, including increasing the availability, understandability, and survivability of the knowledge or information. In semi-structured environments where there exists a predefined decision space and a definite, regular, timely information stream from the external environment the directive paradigm would work reasonably well.

The issue of the potential oversimplification of complex environments must be addressed. Rarely are strategic problem spaces simplistic enough that complete or near-complete information may be obtained, allowing for a linear progression from problem design to choice [23]. This may be the result of tool designers employing an overly analytical view of human decision processes. For example, Mintzberg described the process of decision making in terms of three major components:

- problem identification
- development of alternative solutions
- and selection among the alternatives [24].

Such a partitioned view of decision making appears well suited for mathematical treatment yielding the false perception that the world may be reduced to simple formulas with an optimum choice for each decision [25]. However, recent studies have shown that expert decision makers approach and solve problems in radically different ways than such a simplistic framework would lead one to believe [3, 4]. Naturalistic decision making researchers believe that expert commanders make use of many cognitive capabilities on a daily basis that are non-transferable (e.g. non-codeable) such as intuition and mental simulation [3]. The non-transferability of these human capabilities creates limitations for the directive paradigm and also has resounding consequence for the need to encourage the training, development, and validation of expert decision makers.

When developing technology where the machine will be the principle decision maker it is important to stringently examine what level of "intelligence" the proposed system will possess. The results of this examination would be to determine if the level of intelligence is properly suited for the task at hand, noting specifically what the system is and is not capable of handling. The examination should also attempt to show how the system will affect the mental decision processes of the human decision maker. For example, will the human trust the results of the system, how adaptable will the system be to an individual decision maker, and most importantly, in what capacity does the system improve the decision capability of a commander or strategic command team?

Predictive Paradigm

The predictive paradigm of decision support is characterized by the use of competitive intelligence data and other forms of environmental evidence to assess predictive, probabilistic estimates of event likelihood. The predictive paradigm can be represented by "white board" decision support tools that ask strategic decision makers to layout courses of action and then assess the probabilities for each outcome, event, or consequence pertaining to the CoA. Example approaches include Bayesian and Colored Petri Nets to understand event influence and timing.

The predictive paradigm derives its validity from the axiom that many *events in the world are dependent upon one another*. This event dependency assumes that results of past or

planned future events may be used to predict future outcomes, events, or consequences following the events occurrence. For example, historically an enemy may have followed a set doctrine, thus the adversaries response to a planned action (within this past doctrine) may be predicted. As was the case during the cold war, where both the U.S. and the U.S.S.R. spent years understanding and fine tuning an accurate model of each others doctrinal guidelines. Beyond extrapolating the past, event dependency also allows decision makers to generate inferences regarding future events. For example, if actions a & b are taken against enemy x, enemy x will most likely respond by doing y. The most likely indicates the assessed probability of future state Y occurring.

Tools developed under the predictive paradigm have achieved a measure of success in recent experiments but also a measure of criticism. In an effort to stave off criticism from focusing on any one tool in particular, which is not the purpose of this paper but rather to challenge designers to question the basic assumptions of their approaches, the names of the particular tools will be omitted. In stating that, recently developed predictive tools have been observed to have benefits in terms of increasing the level of analysis and reasoning commanders must perform over a set of potential courses of action. However predictive tools require decision makers to engage in probability estimation, a skill which humans have consistently performed poorly at. Many researchers have advised against attempting to assign probabilities to events or trends. Attempting to define probabilities is difficult. To do so will cause the planning team to dissipate a lot of energy for no real advantage [26].

In addition, if a decision maker trustfully employs a probabilistic tool; it signifies that he or she believes that the numeric estimates being assigned to future events bear a somewhat direct and meaningful relationship to the eventual outcomes of those events. Essentially the decision maker believes the probabilistic model accurately portrays the future environment with some degree of certainty. Thus to improve the model is to improve ones understanding of the future environment. However this may unintentionally change the task of strategy development to being a matter of understanding the future by labeling it [27], rather than a matter of continually re-evaluating the evolving situational environment.

When developing technology under this paradigm it is important for developers to understand the needs of a strategic decision maker as well as the difficulty of prediction in a complex environment. Predictive tools must convey an appreciation of understanding all possible future states to the decision maker, otherwise constructed predictions will yield a dangerously bounded perspective of events to come, overlooking new opportunities and risks [26, 28].

Emergent Paradigm

Within the emergent paradigm, the goal of technology is to help the human strategic decision maker *emerge* with a greater understanding of how the future competitive landscape will take shape in the terms of potential future scenarios. At the heart of the

emergent paradigm is the belief that *at a strategic level, the future is wildly unpredictable and can not be treated in a logical, predefined formulation*. In a classic article, Simon noted that . . .

> "many, perhaps most, of the problems that have to be handled at middle and high levels in management have not been made amenable to mathematical treatment, and probably never will" [19].

The emergent paradigm by nature is meant to improve the strategic decision maker's appreciation for the vast uncertainty surrounding future events. The paradigm focuses tool development efforts on aiding the human expert to observe and reflect rather than to formulate and estimate. Example approaches are based upon scenario generation, planning, and analysis.

To address the unpredictable nature of future environments, both researchers and practitioners have employed scenario planning since the 1970's [29]. We will use the Brauers and Weber scenario definition: a description of a possible future state of an organization's environment considering possible developments of relevant interdependent factors in this environment [28]. Scenarios are a natural fit for the emergent paradigm. Their development encourages an exhaustive, creative look at future possibilities and encourages the discovery, inclusion, and consideration of *outlier events* (unlikely or seemingly unfeasible events) in the strategic planning process. The strategic use of scenarios has been formalized in numerous methodologies both analytical and experiential. Central to both is the need for strategists to run through each possible uncertain future, allowing them to work through the importance, interrelationships, and consequences of the uncertainties involved [30].

The emergent paradigm has numerous advantages when applied to the strategic level of conflict. Tools developed under this "school of thought" aid the human decision maker to develop situational awareness, consider the many possible ways a situation may evolve, and ultimately formulate a dynamic, response strategy that incorporates an appreciation for the breadth of possible future scenarios. Typically this strategy development process involves first generating a comprehensive set of future scenarios by varying the potential actions/fluctuations/responses of situational military, economic, political, and environmental actors, then monitoring the evolving adversarial environment to determine which of the developed potential future scenarios most closely approximates the current environmental situation. In this way the emergent paradigms focus is placed upon understanding and monitoring the future as an evolving process, rather than on forecasting the future based upon probabilistic predictions and corresponding assessments.

It is important to note that there have been many analytic approaches to model the scenario analysis process mathematically, such as cross-impact analysis, the Brauers and Weber method, and fuzzy scenario analysis [28, 31, 32]. But it is principal to recognize that such methods represent a divergence from the major "school of thought" of the emergent paradigm. Granted that adding an analytical component to the process can be

beneficial, it however focuses the intention of the strategic decision maker inward towards manipulating identified scenarios rather than outward, towards the ever evolving adversarial environment. These analytical, typically probabilistic methods will possess many of the same characteristics of approaches encountered in the predictive paradigm.

Scenario planning has several limitations as a tool of the emergent paradigm. Depending on the breadth and depth of the scenarios, their development may be costly in terms of time, energy, and resources. Another issue arises when environmental uncertainty increases to the point where the number of unknown unknowns greatly exceeds the number of known unknowns [33]. The primary role of a strategic tool in such an incomprehensible uncertain environment would be to aid in transforming unknown unknowns into known unknowns, a task focused less on planning and more on intelligence, surveillance, reconnaissance efforts.

AFRL-IF EBO Tool Development Summary

Applying the low-resolution decision support paradigm framework articulated in this paper to the AFRL/IF EBO Tool list produced the following summary classification chart (see appendix for tool descriptions).

AFRL/IF EBO Tools by Predominant Paradigm*

Predictive Paradigm	**Directive Paradigm**
Causal Analysis Tool Fusion for EBO Holistic C4I Human Factors Modeling Tool Effects-based Wargaming Simulation Adv. Modeling for Dynamic CoA analysis Dynamic CoA Development	
Autonomous Paradigm	**Emergent Paradigm**
Center of Gravity Analysis Tool Target Systems Analysis Athena	Strategy Development Tool (loosely) Effector (loosely)

*Tools not far enough along in development to be classified include the Complex Adaptive Systems (CAS) and Air Operations Center Process Assessment Tool (AOC / PAT).

The most striking aspect of this diagram is the overwhelming number of tools being developed under the predictive paradigm by AFRL/IF. Tool development practices within the organization have undoubtedly favored a predictive posture with an anon AFRL/IF developer stating first-hand “If you don’t predict, what else would you do?” No reviewed tools fit clearly under the directive paradigm. The tools listed under the autonomous paradigm (e.g. COG-A, TSA, & Athena) are all only partially autonomous tools but the school of thought that developed

them was of an automated origin, thus in this low-resolution framework they have been placed in the autonomous paradigm.

The Strategy Development Tool (SDT) developed by Alphatech and it's sister tool Effector developed by ISX have been listed under the emergent paradigm because the tools are human centric, however the method of decision support is only loosely emergent. SDT and Effector both simply provide a "white-board" tool that commanders may use to articulate potential courses of action within an effects-based taxonomy and framework. These tools do not help commanders consider the breadth of possible future that may occur or in any way foster an emergent thought process.

Conclusion

Effects-based operations is currently being supported by a variety of tools which have been developed under all four of the preceding paradigms. It is imperative that technology designers be aware that each paradigm has its own inherent advantages and limitations. The insight gained from questioning the basic assumptions of tool development approaches may help developers avoid the adverse unintended consequences made possible from potential "blind spots" that the tool may create in the decision maker's perception of environmental threats. A true cause for concern may be that the irrationality of terrorist actions actually increases their chances of inadvertently successfully targeting a "blind spot". For example, as enemies of state and country no longer have a homeland at risk and thus may be willing to chance using weapons of mass effect indiscriminately. In such an environment decision makers will face hypercompetitive pressure that will require the decision technology designed to support their strategy formulation be meticulously analyzed, questioned, tested, and evaluated.

In the process of information age transformation, experimentation and evaluation will become the foundational pillars upon which further understanding of decision support paradigms will rest. To further understand specifically how a particular technological concept, approach, or technology impacts human and organizational strategic decision processes will require a continuous experimentation campaign, or series of experiments that test and evaluate the efficacy of the object of interest [9, 20]. These evaluative experiments will also serve as the primary vehicle to analyze the underlying assumptions of current EBO tool development practices. Any attempt to codify aspects of the strategic effects-based CoA generation process will inherently structure and affect human decision making thought processes and activity, thus all effects-based strategy formulation tools (and arguably all tools in general) must be rigorously tested and evaluated to determine the tools impact on human cognitive processes. The decision support paradigms articulated in this paper are offered to provide an aggregated vantage point upon which the basic assumptions of current EBO tool development practices may be viewed and questioned. The revision and expansion of this vantage point is inevitable and welcomed in light of future testing and evaluation.

Appendix

The Air Force Research Laboratories Information Directorate (AFRL/IF) has been addressing in recent years the need to develop technologies in support of effects-based operations. To date AFRL/IF has two core technologies under its EBO development thrust being the Causal Analysis Tool (CAT) and the Strategy Development Tool (SDT), however several other efforts are at various states in the proverbial development "pipeline" and a few efforts have met with limited results and thus have been terminated. Efforts that are still in the development "pipeline" include Fusion for EBO (FEBO), Target System Analysis (TSA), Center of Gravity Analysis Tool (COG-A), and the Holistic C4I-Human Factors Modeling Tool. The only terminated effort uncovered was the Effects-based Operations Wargaming Simulation (EBOWS).

AFRL/IF EBO Tools Development Efforts List

Causal Analysis / Operational Assessment Tool (CAT/OAT) – Predicts the probability of achieving a commander's intent for a blue CoA. CAT helps commanders reason over cause/effects relations for a given campaign over time, providing for tradeoff analysis and drill down capability. CAT provides the ability to perform operational assessment based upon fused BDA/PBA evidence.

Strategy Development Tool (SDT) – Supports development of an effects based CoA. SDT decomposes commander's intent into hierarchies of desired effects, tasks, and causal linkages. SDT forces commanders to structure and articulate their plans in an effects based taxonomy and process framework.

Fusion for EBO (FEBO) – The tool is used to determine if measures of effectiveness (MOEs) and indicators from SDT are being met as well as to provide accrued and fused multi-INT evidence to SDT/CAT using the AFRL Advanced Sensor Fusion Architecture.

Center of Gravity Analysis Tool (COG-A) – COG-A represents a semantic information integration effort to create a single ontology-based model that provides a "system of systems" view of adversary capabilities. COG-A provides "dependencies linkage" reasoning to support effects-based COG analysis as well as automated integration of information from multiple data sources into the single ontology-based model.

Holistic C4I-Human Factors Modeling Tool – Effort aims to develop an architecture to posture CAT's Dynamic Bayesian Networks behavioral models and responses to proposed psychological or influence operations for independent analysis of for reuse by NASIC's C2 process models.

Effects-based Operations Wargaming Simulation (EBOWS) – Analytic tool for CoA comparison based on engagement-level, attrition-based wargaming.

Target Systems Analysis (TSA) – Tool allows users to develop candidate target lists based upon given effects-based mission objectives.

Athena – Tool provides a TSA and COG analysis capability that integrates the Warden, Barlow, and PMESII models and focuses on doctrinally correct TSA for Joint Pub 3-60.

Effector – Tool used to build effects-based CoAs. Effector is ISX's EBO ontology strategy development tool or SDT. SDT was developed by Alphatech.

Dynamic Course of Action Development (DCOAD) – Tool designed to predict and asses the impact of emerging threats against plans in development by continuously monitoring the battlespace for emerging targets. The tool also updates CoA assessment.

Complex Adaptive Systems (CAS) – Two phase 1 efforts looking at how CAS theory may apply to effects based operations and CoA generation.

Adversary Modeling for Dynamic Course of Action Analysis – Development of techniques for generating hypothesis of adversary actions and identify the associated goal or rational. The tool would utilize Bayesian Networks to capture adversary computational model for actions and rational.

Air Operations Center Process Assessment Tool (AOC PAT) – Executable model of the AOC for the analysis of process improvement.

References

1. Alberts, D., *The Unintended Consequences of Information Age Technology*. Vol. 2003. 1996, Washington, DC: National Defense University, http://ndu.edu/books.
2. Courtney, J.F., *Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS.* Decision Support Systems, 2001. **31**: p. 17-38.
3. Klein, G., *Sources of Power*. 1999, Cambridge, MA: MIT Press.
4. Klein, G., *Understanding & supporting decision making: An interview with Gary Klein.* Information Knowledge Systems Management, 2001. **2**(4): p. 291-297.
5. Mann III, E.C.U., Retired),, G.U. Endersby, Retired),, and T.R. Searle, *Thinking Effects: Effects-Based Methodology for Joint Operations*. College Of Aerospace Doctrine, Research And Education Paper No. 15. 2002: Air University.
6. Wentz, L.K. and L.W. Wagenhals. *Effects Based Operations for Transnational Terrorist Organizations: Assessing Alternative Courses of Action to Mitigate Terrorist Threats*. in *Command and Control Research and Technology Symposium*. 2004. San Diego, CA.
7. Deptula, B.G.D., *Effects-Based Operations: Changes in the Nature of Warfare*. 2001, Arlington, VA: Aerospace Education Foundation.
8. Deptula, D.A., *Firing for Effect: Change in the Nature of Warfare.* Defense and Airpower Series, 1995.
9. US_Joint_Forces_Command, *A Concept Framework for Effects Based Operations*, in *White Paper Version 1.0*, C.D. J9, Editor. 2001: Norfolk, VA.
10. Air_Combat_Command, *Effects Based Operations*, in *ACC/XP*. 2002: Langley AFB VA.
11. Lowe, D. and S. NG. *Effects-based operations: language, meaning and the effects-based approach*. in *Command and Control Research and Technology Symposium*. 2004. San Diego, CA.
12. Smith, E.A., *Effects Based Operations: Applying Network Centric Warfare in Peace, Crisis and War*. 2002, DOD Command and Control Research Program.
13. Davis, P., *Effects-Based Operation (EBO): A Grand Challenge for the Analytical Community*. 2001, Santa Monica:CA: Rand.
14. Tzu, S., *The Art of War: In Sun Tzu's Own Words, translated by Gary Gagliardi*. 1999, Seattle, WA: Clearbridge Publishing.
15. Hopple, G.W., *Decision aiding dangers: the law of the hammer and other maxims.* Systems, Man, and Cybernetics, 1986. **November/December**: p. 948-963.
16. Sage, A.P., *Decision Support Systems Engineering*. 1991, U.S.A: Wiley & Sons.
17. Mirchandani, D. and R. Pakath, *Four models for a decision support system.* Information & Management, 1999. **35**(1): p. 31-42.
18. Gilad, B., *Business Blindspots: Replacing Your Company's Entrenched and Outdated Myths, Beliefs and Assumptions With the Realities of Today's Markets*. 1993: McGraw-Hill.
19. Simon, H.A., *The New Science of Management Decision*. 1960, New York: Harper & Row.

20. CCRP/NATO, *Code of Best Practice for C^2 Assessment: Decisionmaker's Guide*. Revised 2002 ed. 2002, Washington:DC: CCRP, http://www.dodccrp.org.
21. Parasuraman, R., T. Sheridan, and C. Wickens, *A model for types and levels of human interaction with automation.* Systems, Man, and Cybernetics, 2000. **May/June**: p. 286-297.
22. Alberts, D., et al., *Code of Best Practice for Joint Experimentation*. 2002, Washington, D.C.: DOD/CCRP.
23. Lindley, D.V., *Making Decisions*. 1985, New York: Wiley.
24. Mintzberg, H., D. Raisinghani, and A. Theoret, *The structure of "unstructured" decision processes.* Administrative Science Quarterly, 1976. **21**: p. 246-275.
25. Mitroff, I.I. and H.A. Linstone, *The Unbounded Mind: Breaking the Chains of Traditional Business Thinking*. 1993, New York: Oxford University Press.
26. Finlay, P.N., *Steps towards scenario planning.* Engineering Management Journal, 1998. **8**(5): p. 243-246.
27. Wilson, F., J. Wilson, and A. Smith. *Computer-based systems: a discussion of their application to managerial decision-support*. in *Special Interest Group on Computer Personnel Research Annual Conference*. 1993. St Louis, Missouri, United States: ACM Press.
28. Brauers, J. and M. Weber, *A New Method of Scenario Analysis for Strategic Planning.* Journal of Forecasting, 1988. **7**: p. 31-47.
29. Postma, T. and F. Liebl, *How to improve scenario analysis as a strategic management tool?* Technological Forecasting & Social Change, 2004. **Article in Press**.
30. Schwartz, P., *The Art of the Long View: Planning for the Future in an Uncertain World*. 1991, New York: Doubleday Currency.
31. Sarin, R.K., *A sequential approach to cross impact analysis.* Futures, 1978. **10**(53-62).
32. Wang, H.-F. *A fuzzy approach to scenario analysis in strategic planning*. in *Fuzzy Systems Conference Proceedings*. 1999. FUZZ-IEEE '99: 1999 IEEE International.
33. van der Heijden, K., *Scenarios: The Art of Strategic Conversation*. 1996, Chichester: Wiley.